Amendments to the Specification:

Please add the following new paragraph on Page 1, above line 1:

--CROSS REFERENCE TO RELATED APPLICATIONS

Applicants claim priority under 35 U.S.C. §119 of Spanish Application No. P200302003 filed August 14, 2003. Applicants also claim priority under 35 U.S.C. §365 of PCT/ES2004/000378 filed August 14, 2004. The international application under PCT article 21(2) was not published in English.--

Page 1, please amend the first paragraph as follows:

The present invention consists of a method that allows the power of an input electromagnetic signal to be divided into two equal-power signals with a relative phase difference of 180° and an equal propagation delay. ~~Said~~ This method makes use of a coupler consisting of two parallel guides disposed close to one another in a photonic crystal. Both two-dimensional (2D) and three-dimensional (3D) crystals could be used as the underlying concept is the same. The advantages of the divider structure are its small size, which makes it suitable for integration ~~into~~ of numerous ~~divider~~ dividing units as functional units of more complex devices, the high operational

bandwidth, which is an advantage with respect to other methods for dividing power which are sensitive to frequency, and synchrony between the output signals from the device, which is an essential feature for high-speed signal processing.

Page 1, line 4 from below, to page 2, line 23, please amend this paragraph as follows:

Photonic crystals are formed from materials with a dielectric constant that varies periodically in one, two or three spatial dimensions. This periodicity gives rise to the appearance of frequency bands in which signal propagation is not permitted inside the crystal. These forbidden frequency bands are commonly known as the Photonic Band Gap (PBG). Light propagation can be controlled by inserting defects that alter the periodicity of the crystal. The insertion of linear defects leads to the appearance of guided modes at frequencies within the forbidden band allowing the propagation of light only in the defect created. Although total control of the propagation of light is achieved by using 3D photonic crystals, control of light in three dimensions can also be achieved with planar 2D photonic crystals, thus reducing the cost and complexity of manufacture. In this case, the light is confined to the direction perpendicular to the plane of the crystal if the dielectric constant of the materials above and below the crystal is less than the

dielectric constant of the defect created in the crystal. The main advantages of the devices based on photonic crystals are a considerable reduction in size, allowing highly integrated optical circuits to be produced, and the possibility of implementing curved guides with radii of the order of the wavelength of the signal that is being propagated without significant losses, which is essential for the ~~microphotonic~~ development of microphotonics.

Page 2, line 13 from below, to page 3, line 4, please amend this paragraph as follows:

Due to the scaling properties of Maxwell's equations, photonic crystals can be ~~produced that~~ made to have a forbidden band in any spectral range provided the structure is appropriately scaled and provided materials are chosen that have suitable properties in the chosen spectral range. As it is extremely costly to manufacture structures in the visible or infrared frequencies, in which the spatial periodicity should be less than one micron, photonic crystals ~~and functional properties~~ have been implemented ~~which are based on~~to work at microwave frequencies where the periodicity is of the order of cm. To do this, bars of dielectric material with a high refraction index are used that form periodic ~~network~~ lattices in air. The properties of these structures can by and large be extrapolated to the structures corresponding to optical frequencies, but with the

advantage that at microwave frequencies, manufacture and measurement of the properties is much easier.

Page 3, please amend the paragraph beginning on line 5 as follows:

In a photonic crystal, a waveguide can be created from a chain of equally spaced cavities or point defects along a certain direction of the crystal. This type of guide is known as a coupled cavity waveguide. The propagation along these guides is explained by photons jumping between adjacent cavities due to overlap of the evanescent field tails. The coupled cavity waveguides have certain characteristics that make them particularly interesting: on the one hand, a theoretical expression can be derived for the dispersion ratio of the guide modes from a tight-binding approach~~es~~ used in solid-state physics. On the other hand, transmission along curves with very tightly curved radii is very efficient provided that symmetry of the cavity mode is appropriate. In addition, the group velocity of this type of guide is very low, tending to zero at the edges of the band, and so highly efficient non-linear processes are expected in this type of guide, as well as high dispersion that could be of use in a number of applications.

Same page, line 13 from below, to page 4, line 13, please amend this paragraph as follows:

On the other hand, couplers in photonic crystal technology can be implemented in the same way as used by other more mature technologies, such as integrated guides or fiber optics: disposing two parallel wave guides close to one another. If both guides are identical and ~~monomodal~~ single moded when placed in proximity, the two interact and the guide mode of an isolated guide divides into two modes for the complete system of the two parallel waveguides. These modes have even and odd symmetry with respect to the plane equidistant from the guide ~~axes~~ axis. In addition, these modes have different propagation constants, implying that they travel at a different velocity along the coupler. This behavior causes a signal to be excited in one of the two guides, after a certain distance the wave passes to the adjacent guide and, once again, returns to the original guide after covering the same distance ~~and returns to the guide that contained it originally~~. That is, there is a periodic transfer of power between guides. In 2D photonic crystals, couplers have been proposed and studied formed from guides made by completely eliminating a row of cylinders in dielectric cylinder structures over air. The ~~functioning~~ performance of a directional coupler has also been shown experimentally at optical frequencies in a planar photonic crystal with air holes on a silicon substrate. In addition, a coupler has been proposed in a 2D photonic crystal of air holes in dielectric for commutation applications.

Page 5, line 9 from below, please amend this paragraph as follows:

The advantages of the divider structure are its small size, which makes it suitable for integration ~~with~~ of several ~~divider~~ dividing units as functional units of more complex devices, large bandwidth, and synchronization of the two output signals of the structure, which allows high-speed signal processing.

Same page, line 3 from below, to page 6, please amend this paragraph as follows:

By means of the same method, a divider could be obtained with the output signals in-phase if, instead of odd mode, the even mode of the coupler is used.

Page 6, lines 1 to 8, please amend this paragraph as follows:

The photonic crystal comprises a ~~network~~ lattice of cylinders grouped in columns that can adopt any value for the ~~network~~ lattice constant (distance between cylinders closest to one another), was well as any radius and height of the cylinders. Likewise, the method is applicable for any difference of refraction indexes between the material of the columns, the material that surrounds the columns and the material above and below the crystal.

Same page, lines 10-11, please amend this paragraph as follows:

The photonic crystals can adopt any type of ~~network~~ lattice, particularly a triangular ~~network~~ lattice or square ~~network~~ lattice.

Same page, fifth paragraph, please amend this paragraph as follows:

To complement the description being made and in order to facilitate a better understanding of the characteristics of the invention, in accordance with a preferred example of a practical embodiment thereof, as an integral part of ~~said~~ such description, a set of figures is included in which, for illustrative purposes, and in no way limiting, the following has been represented:

Page 9, line 18, to page 10, line 5, please amend this paragraph as follows:

In order to describe the present invention and offer results that verify the behavior, as a preferred embodiment, a 2D photonic crystal is chosen as shown in Figure **2**. This photonic crystal consists of a hexagonal ~~network~~ lattice with a ~~network~~ lattice constant *a* (distance between the center of the cylinders closest to one another) of dielectric cylinders (10) with a high refraction index (permittivity ε_1) and radius *r* on a medium (11) with a low refraction index (permittivity ε_2). The structure is periodic in the

plane in which the cylinders are distributed and is described by the directions ΓK and ΓM, whereas it is constant in the direction perpendicular to the plane of periodicity. This photonic crystal has a forbidden band for modes with transversal magnetic polarization (TM), that is, modes with the electric field in the direction perpendicular to the plane of the crystal. This embodiment is selected for verification at microwave frequencies in the laboratory. However, the present invention could be realized in 2D crystals with square symmetry, with another transversal form of the cylinders, interchanging materials of high and low refraction index, and even using a 3D photonic crystal without losing its general characteristics.

Page 10, please amend the paragraph beginning on line 6 as follows:

Figure **3** shows an example of a waveguide (12) created in the 2D photonic crystal of Figure **2** by means of suppression of a row of cylinders ~~in~~ <u>along</u> the ΓK direction. On creating the guide, there is a mode with TM polarization confined to the linear defect with frequencies within the forbidden band, and so the linear defect acts as a waveguide. It is also possible to create a guide from coupled cavities (13) as shown in Figure **4**. In this case, a chain of cavities is created and propagation is due to photons jumping between

neighboring cavities due to overlap of the tails of the field confined to the cavity. In the particular case of Figure **4**, the cavities are created by eliminating a high ~~refraction~~ refractive index cylinder and the separation between them is $d = 2a$ ~~in~~ along the ΓK direction. Similarly, for the waveguide (12), there is a TM guide mode with frequencies within the forbidden band.

Page 11, line 10 from below, to page 12, line 23, please amend this paragraph as follows:

Figure **6** shows the coupler formed by the two coupled cavity waveguides (13). The two guides (13) are separated by a region (14) which in this case consists of three rows of cylinders of high refraction index. Figure **8** shows the structure of bands of the guide modes for TM polarization of the coupled cavity waveguide (13) and the coupler of the coupled guides of Figure **6** for a separation of a row of cylinders of high refraction index in the region between the guides (14). As in Figure **7**, on the vertical axis, normalized frequencies are represented in units of c/a and on the horizontal axis, the propagation constants limited to the first Brillouin zone. The guide mode of the isolated guide is shown with a broken line (21), and the even modes (22) and odd modes (23) of the coupler as a solid line. Here, it is observed that the even and odd modes are much more uncoupled from one another with respect to the bands of the

coupler of Figure **5**. This is due to the fact that in the coupler of Figure **6**, the coupling is of the same order of magnitude in the longitudinal direction of the guides (ΓK) as in the transversal direction (ΓM), whereas in the coupler shown in Figure **5**, coupling is much stronger in the longitudinal direction due to a smaller separation between adjacent cavities. Thus, we have a large spectral region (24) in which only the odd mode exists and which can be used to implement the power divider with a phase difference of 180°. The spectral region where only the even mode is present (26) is not as ~~broad~~ wide, and the region where both modes coexist is almost indiscernible (25) due to extensive uncoupling. These are the results for the preferred embodiment, but a design could be drawn up in which the even and odd modes did not coexist in frequency and the whole of the region of the odd mode (23) would be available to implement the divider.

Page 13, line 11, to page 14, line 4, please amend this paragraph as follows:

In order to verify the nature of the power divider and 180° ~~dephasing~~ phase-shifting of the proposed method, in Figure 10 a simulation is shown with a method of finite differences in the time domain of the electric field distribution parallel to the axis of the cylinders for a monochromatic wave with a normalized frequency 0.44 (which lies in the operating range of the). On introducing this

signal into the input port (28), the signal reaches the section of the coupler that, in this case, consists of $N = 6$ cavities, and excites the odd mode. The field maxima are shown in white shades and the minima in black shades. It is observed that in the region of coupling, the maxima of one of the guides correspond to minima with the adjacent one, and vice versa, which confirms that the exciting mode is of odd symmetry. At the output, use is made of the property of spatial periodicity of the 2D photonic crystal to divide the guides of the coupler into two output points (29) and (30). The odd symmetry is maintained at the output ports, and so the phase difference between them is 180°. In addition, the path covered by the two signals through the structure is identical and so they are synchronized. This property is very important, as high speed signals can be used without delays at the outputs. If, for example, it is desired to implement a divider with a phase difference of 180° from a divider with a difference of 90°, this could be done by adding an additional path in one of the output ports that adds an extra phase difference of 90°. However, this ~~route~~ <u>mechanism</u> will also add to the propagation delay and so the condition of synchrony between output signals would not be met, unlike the proposed method.

Page 15, line 10, to page 16, line 26, please amend this paragraph as follows:

The simulation method available does not allow phase measurements to be obtained and so the divider shown in Figure **9** was

implemented in the laboratory using 300 bars of alumina with constant ε_1 = 10.3, height 10 cm and radius 2 mm. To generate signals and perform the measurements of amplitude and phase, a vectorial network analyzer was used of up to 50 GHz. For r = 0.133a as in the simulations, a = 1.5 cm was chosen. For the defect-free crystal, as shown in Figure **2** and for a TM polarized signal, a forbidden band was observed between 7.36 and 11.7 GHz ~~in~~ along the ΓK direction. Then, a guide was introduced like the one in Figure **4** and a guided band was observed for TM polarization between 8.53 and 9.05 GHz. This guided band corresponds to mode (21) in Figure **8**. Afterwards, the divider shown in Figure **9** with N = 4 cavities was introduced and transmission measurements were made of amplitude and phase that are shown in Figure **12**. The amplitude response is shown with the solid line (37) for the output port (29) and with a broken line (38) for the output port (30). The phase response is shown with a solid line (39) for the output port (29) and a solid line (40) for the output port (30). Also shown are the three spectral regions (32), (33) and (34) of differing behavior of the divider already included in Figure **11**. The zone (32) is the one that corresponds to the 180° divider, and in phase response it is observed that the difference in phase between the two outputs (50) and (51) is 180° approximately over the whole range. The difference in amplitude response (37) and (38) in the spectral range (32) is due to imprecision in the implementation of the structure, unwanted external reflections as well as to lack of modal adaptation between the different sections of the divider. The range of the

divider is 180° and it occupies a spectral width of around 300 MHz, that is, a relative bandwidth of 3.45 %, sufficient for numerous applications. By way of a simple example, in the optical band of 1550 nm, used in optical communications, a bandwidth greater than 50 nm would be obtained, suitable for applications in optical multiplex networks by division of wavelength. In the range (33), both even and odd modes are excited and there is no stable behavior of the amplitude and phase outputs. Finally, the region (34) would correspond to the zone of excitation of the even mode, which is confirmed if we observe the phase response of the structure where we see that (39) and (40) are in phase in this interval. The response in amplitude for the region (34) shows ~~an~~ equilibrium in the output power at both ports (29) and (30). The total power in the excitation region of the even mode (34) is smaller than that in the excitation region of the odd mode (32) because the even mode (22) has a flatter frequency than the odd mode (23), and so greater lack of modal adaptation will occur and a lower global transmission efficiency.